



GENERATION OF IDF CURVES IN ARID AND SEMI-ARID AREAS: CASE STUDY HURGHADA, EGYPT

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ABSTRACT

Intensity-Duration-Frequency (IDF) curves are commonly used in water resources projects and hydrological analyses. One of the most important requirements for creating IDF curves is the actual distribution of rainfall intensity during the period of rainfall, but usually short-duration rainfall records are rare in arid regions while daily rainfall data are available. Hydrologists can generate short-duration rainfall data from daily rainfall data through using the Natural Resources Conservation Service (NRCS) standard synthetic rainfall distributions. The main purpose of this paper is to show the procedure to be followed in developing the IDF curves using the daily rainfall data recorded at the Hurghada weather station. Frequency analysis of the observed rainfall records was performed using HyfranPlus software. The gamma distribution is the most widely accepted probability distribution in this research.

Keywords: IDF, NRCS rainfall distributions, Rainfall intensity, arid regions.

Cite this Article: Neveen B Abd El-mageed, Ahmed I Abdallah and Elzahry F Mohamad, Generation of IDF Curves in Arid and Semi-Arid Areas: Case Study Hurghada, Egypt, *International Journal of Civil Engineering and Technology (IJCET)*, 12(11), 2021, pp. 26-33.

<https://iaeme.com/Home/issue/IJCET?Volume=12&Issue=11>

1. INTRODUCTION

Hurghada, Egypt, is one of the semi-arid regions of the Red Sea. The Red Sea coast has a dry climate and a scarcity of rainfall events, but recently it has witnessed increases in rainfall rates, which in some cases led to severe flash floods. For example, in 01 NOV 1994, the Eastern Desert received a large amount of rainfall 60mm [1]. Also, on November 16th, 17th and 18th, 1996, a heavy rainstorm of 40 mm occurred [2]. More recently, on March 9th, 2014 and on the 27th of October, 2016, heavy rainstorms hit several parts of Hurghada Road and El Gouna city

resulting in damage to the tourist villages and many deaths [3]. High-resolution rainfall data are important in most water resource assessment studies, but they are not available in many parts of the world and in arid and semi-arid areas in particular, given the high cost of installing recording rain gauges. Often the available rainfall records are daily or annual. To tackle this problem, hydrologists can convert observational daily rainfall data into shorter-duration series. One of the most important hydrological analyses, The construction of intensity–duration–frequency Curves (IDF Curves) are graphic representations that illustrate the relationship between rainfall intensity and storm duration for a given return period [4]. Engineers have been using IDF curves in the United States since 1935. David Yarnell developed the first "Intensity Frequency Maps" for the United States in 1935. For most water resources planning and management projects, rainfall intensity analyses, especially IDF curves for the different return periods, are necessary [5]. Hydrology and engineering researchers in Saudi Arabia have developed the IDF curve for example (Al-Wagdany 2021[6]; Al-Amri and Subyani 2017 [5]; Elsebaie 2012[7]). Also, researchers have proposed different procedures for developing the IDF curve for arid and non-arid regions through approaches based on statistical analysis of data. E.g. Bell (1969) [8] and Chen (1983) [9] derived IDF formulas for specific regions of the United States. The IDF curves can be derived from frequency analysis of short-duration precipitation data or by applying many of the empirical formulas available. In Sylhet city, they applied the empirical reduction formula developed by the Indian Meteorological Department to produce short-duration rainfall from daily rainfall [10]. In Saudi Arabia, Al-Wagdany et al (2021), generated of IDF curves based on NRCS synthetic rainfall hyetographs and daily rainfall records. Synthetic rainfall hyetographs are the most common technique for dividing total rainfall into shorter-duration periods [11]. The most common rainfall temporal distributions are the four synthetic NRCS distributions (Types I, IA, II, and III [12]) developed by the National Resource Conservation Service (NRCS). Type I and IA are recommended for the West Coast of the USA, Type III for the East Coast of the USA and the Gulf of Mexico area characterized by severe tropical storms, and a Type II hyetograph for the rest of the USA. The temporal distribution of rainfall in Egypt has not been well investigated due to the unavailability of short-duration rainfall records as the available rainfall records are daily data. The main objective of this research is the possibility of using the daily rainfall data available in Hurghada station, coupled with NRCS temporal dimensionless rainfall distributions to generate short-duration rainfall data for the Hurghada region in Egypt. The generated short-duration rainfall series are used to create the IDF curves. In this research, IDF curves were developed for different periods ranging from 10 minutes to 1440 minutes and five different return periods of 5, 10, 25, 50 and 100 years. The paper proposes an approach to construct the IDF curves using daily data from the Hurghada rain gauge

2. SEARCH AREA

The Hurghada City is located on the western shore of the Red Sea it is bounded by latitudes (27 10` and 27 30` N) and longitudes (33 30` and 33 52`E); it is the capital of the Red Sea Governorate. Bordered from the north by the city of Ras Ghareb 150 km away, bordered from the south by the safaga only 60 km away and from the east overlooking the Red Sea coast, and from the west, the mountains of the Red Sea. Its beaches cover 40 km of the Red Sea coast, and its total area is 460.5 km. It is considered the fourth city in size among the cities of the Red Sea Governorate, after the cities of Ras Ghareb, Safaga and Quseir. (See Figure 1).



Figure 1 Hurghada location

3. AVAILABLE HISTORICAL DATA OF RAINFALL

For the study of rainfall intensity, a record of rainfall data for the years 1969 to 2018 for Hurghada station was obtained from the Egyptian Meteorological Authority, and the data is the maximum depth of rainfall during each year. (See Figure 2).

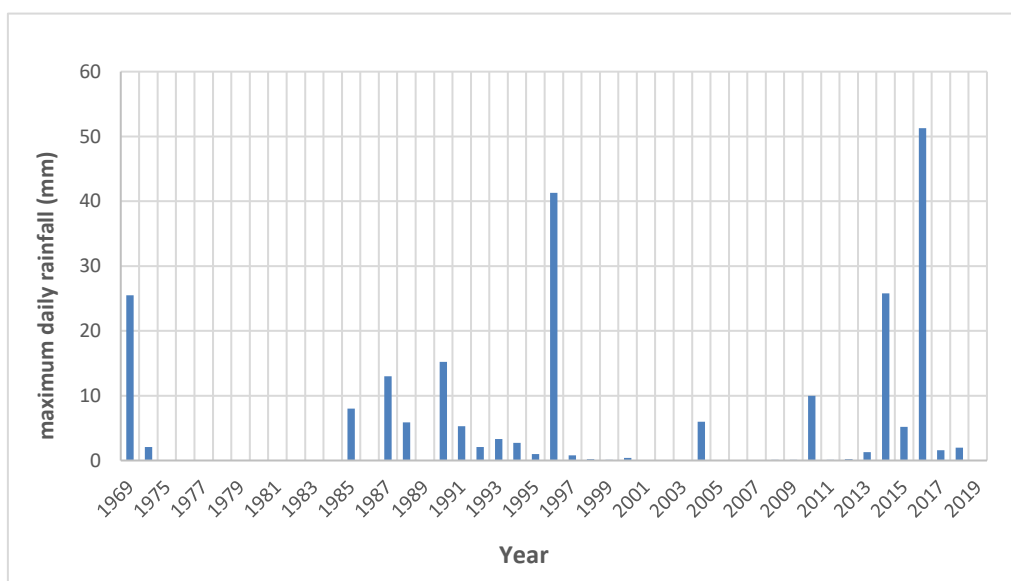


Figure 2 The maximum daily rainfall depth during 47 years (1969-2018)

4. CONSTRUCTING OF IDF CURVES

The depths of future rainfall in arid and semi-arid area cannot be predicted with absolute confidence. As a result, the magnitude and frequency of rainfall should be investigated and assessed using probability principles. In areas where there is no good measurement, rainfall data are short or often absent and this leads to difficulty estimating intensity - time duration - frequency [13]. The IDF curves are developed through the following steps: First step: Analysis of the daily rainfall data collected from the Hurghada station for the years from 1969 to 2018 and Estimation of the maximum depth of rainfall for 2 years, 5 years, 10 years, 25 years, 50 years and 100 years using the appropriate statistical distribution. The second step: Short-duration rainfall data are generated using standard NRCS Type II temporal rainfall distributions. The third step: is to Calculation of the intensity of rainfall per period (from 10 minutes to 1440 minutes) corresponding to the various return periods; 2, 5, 10, 25, 50 and 100. The resulting data is used to develop IDF curves for the same rainfall station.

5. PROBABILITY DISTRIBUTION

Frequency analysis was applied to rainfall data for Hurghada station using the HYFRAN-PLUS program to predict the maximum depth of rainfall in Hurghada for different return periods. The purpose of to carry out frequency analysis, is to use statistical probability distributions to create the magnitude of extreme events (in this case, rainfall) to their frequency of recurrence [14]. The HYFRAN-PLUS program contains 14 statistical distributions that perform hydrological frequency analysis (HFA) for the maximum annual rainfall values of floods to a random sample provided it is independent and identically distributed [15]. Available distributions frequency were selected and a comparison is made between them to choose the most appropriate model for data representation. Then, statistical criteria are used to identify the statistical distribution that fits observed sample data. By choosing the lowest value for the following criteria Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of the comparison indicated that the Gamma distribution is the most appropriate to represent the rainfall data for Hurghada Station (see Figure 3, 4, 5 and 6).

Comparison criteria of the distributions

Return period: WARNING ! The decision-support system (comparison criteria as described in the HYFRAN menu) is still being developped. It should therefore only be used as an indication.

Sample size:

Model	Nb param.	XT	P(Mi)	P(Mi x)	BIC	AIC
Gamma (Maximum Likelihood)	2	57.215	16.67	75.82	159.892	156.899
Lognormal (Maximum Likelihood)	2	456.860	16.67	24.16	162.180	159.186
Inverse Gamma (Maximum Likelihood)	2	5.833	16.67	0.02	176.079	173.086
Exponential (Maximum Likelihood)	2	32.938	16.67	0.00	203.259	200.266
Gumbel (Maximum Likelihood)	2	29.203	16.67	0.00	237.177	234.184
Normal (Maximum Likelihood)	2	35.392	16.67	0.00	264.775	261.782

Figure 3 Comparison Criteria of the Distributions for Station “maximum likelihood”

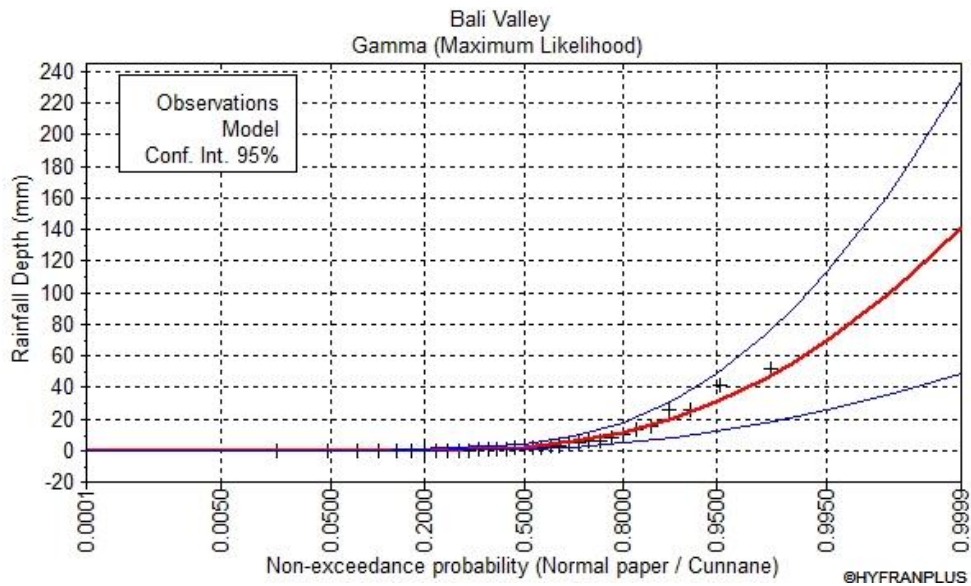


Figure 4 Distribution graph for Gamma “maximum likelihood”

Comparison criteria of the distributions

Return period: WARNING ! The decision-support system (comparison criteria as described in the HYFRAN menu) is still being developed. It should therefore only be used as an indication.

Sample size:

Model	Nb param.	XT	P(Mi)	P(Mi x)	BIC	AIC
Gamma (Method of moments)	2	58.530	16.67	82.90	159.942	156.949
Weibull (Method of moments)	2	58.826	16.67	17.10	163.099	160.106
Pearson type 3 (Method of moments)	3	53.861	16.67	0.00	233.666	229.177
3-parameter lognormal (Method of moments)	3	51.784	16.67	0.00	238.798	234.309
GEV (Method of moments)	3	50.667	16.67	0.00	240.968	236.479
Gumbel (Method of moments)	2	45.279	16.67	0.00	247.381	244.388

Figure 5 Comparison Criteria of the Distributions for Station “method of moments”

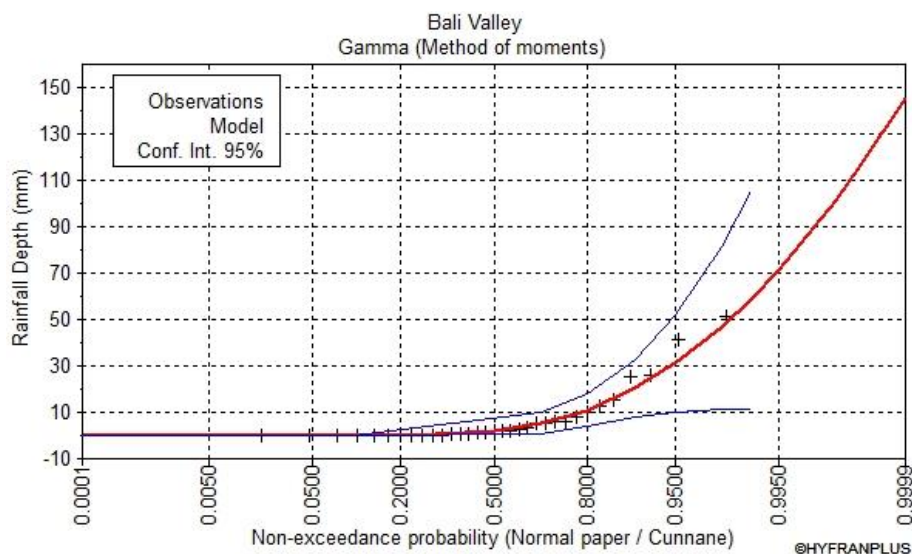


Figure 6 Distribution graph for Gamma “maximum likelihood”

6. RESULTS AND DISCUSSION

In this research, the rainfall depths corresponding to certain return periods were calculated using statistical distribution functions to construction IDF curves from the rainfall data in the study area and these functions are gamma. Synthetic rainfall distributions to convert daily observed rainfall data into shorter duration data are widely used in the USA and other regions of the world by engineers and hydrologists to design and manage hydraulic structures, and have the advantage of being easy to use. In this research, The NRCS type II temporal rainfall distribution has been used to generate short-duration rainfall depths (from 10 minutes to 24 hours) described in (see Table 1). The resulting data is used to develop IDF curves for the study area.

Table 1 Rainfall intensity (mm/ hr) at different rainfall duration using the 24-h type II NRCS distribution

Rainfall Duration	Rainfall Intensity (mm/hr)					
	Return Period (YR)					
	2	5	10	25	50	100
10 min	2.2	11.86	21.82	36.37	48.68	61.88
20 min	1.91	10.31	18.98	31.63	42.34	53.83
30 min	1.49	8.05	14.82	24.7	33.06	42.02
40 min	1.21	6.52	11.99	19.99	26.75	34.01
50 min	1.01	5.52	10.15	16.92	22.65	28.80
1 hour	0.89	4.79	8.82	14.71	19.68	25.03
2 hour	0.52	2.84	5.24	8.73	11.68	14.86
3 hour	0.39	2.10	3.86	6.44	8.62	10.96
6 hour	.23	1.24	2.29	3.82	5.12	6.51
12 hour	0.13	0.74	1.36	2.27	3.04	3.87
24 hour	0.08	0.44	0.81	1.35	1.81	2.30

The intensity duration frequency curve is plotted by using the rainfall intensity of above (see Table 1) for various durations. (See Figure 7) shows intensity duration frequency curve.

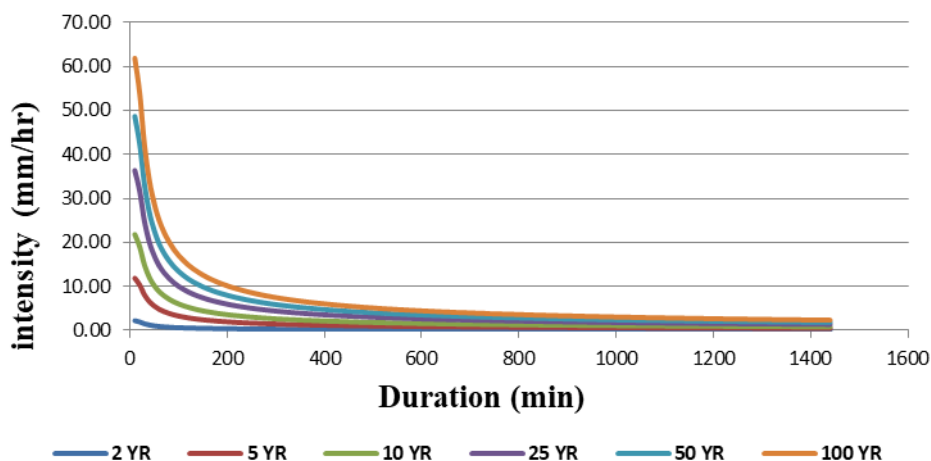


Figure 7

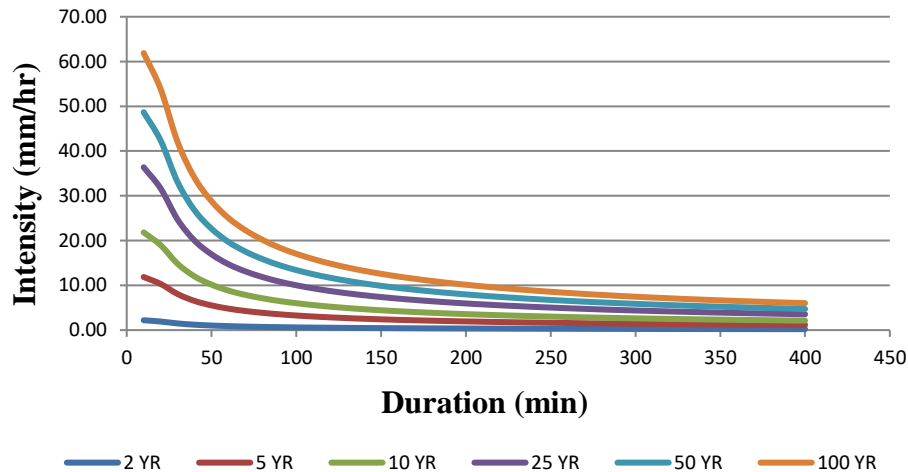


Figure 7 A

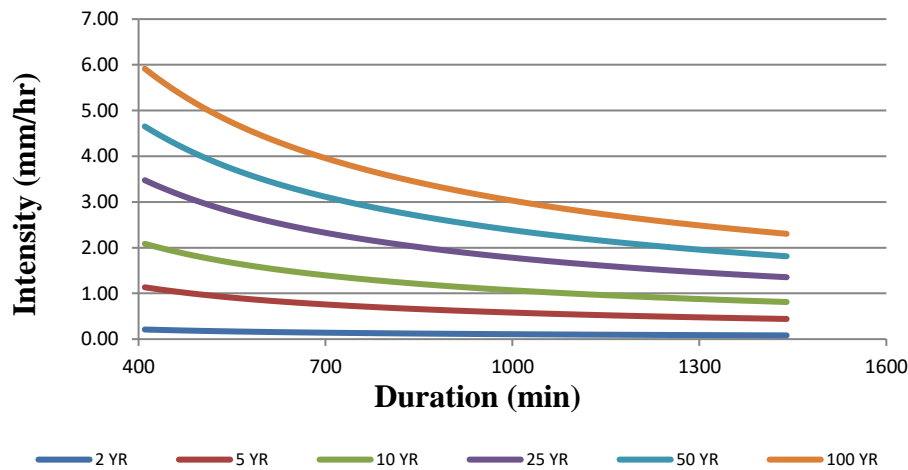


Figure 7 B

Intensity Duration Frequency curves for the study area using Gamma method (Figure 7) from 10 minutes to 24 hours, (Figure 7 A) from 10 minutes to 400 minutes, (Figure 7 B) from 400 minutes to 24 hours

7. CONCLUSION

In this research, for the Hurghada region located on the Red Sea coast, the maximum precipitation depth for different return periods 2, 5, 10, 25, 50 and 100 years was calculated by using the best data distribution method (Gamma distribution). IDF curves was developed using NRCS temporal dimensionless rainfall distributions. The availability of the IDF curves assist engineers in planning and designing water resources projects

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